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NATIONAL RESEARCH COUNCIL OF CANADA

SPACE RESEARCH FACILITIES BRANCH

BLACK BRANT ROCKET AMF-II-115
LAUNCHED AT CHURCHILL RESEARCH RANGE
19 MARCH 1971

Operations Requirement Number 7015

OTTAWA

October 1971

ABSTRACT

This report deals with the engineering aspects of preparing the payload and launching Black Brant rocket AMF-II-115 at 2124 CST, 19 March 1971, at Churchill Research Range into a distinct and sustained auroral event. This vehicle carried a recoverable payload which had previously been flown in Black Brant AMF-II-117 on 18 February 1969 (SRFB 027 dated July 1969 refers). Experiments included auroral spectrum photometry, thin film tests, vacuum ultraviolet photometer and ionization density measurements. Three packages were re-flown, while the thin film test replaced one other experiment. AMF-II-115 performed as scheduled, including soft landing of the payload with good experimental data being obtained, except for the spectrograph which was only partially successful.

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ILLUSTRATIONS

BLACK BRANT ROCKET AMF-II-115 LAUNCHED AT CHURCHILL RESEARCH RANGE - 19 MARCH 1971

The National Research Council of Canada is engaged in a sounding rocket program with various groups from Canadian universities, scientists in the Council and other agencies who are interested in performing measurements in the upper atmosphere with particular reference to auroral activity.

The program is coordinated by the Associate Committee on Space Research of the National Research Council of Canada. Payload engineering, fabrication (except for the experimenters' own equipment), checkout and launching are arranged by the Space Research Facilities Branch through contracts to various government agencies and Canadian industry.

This report deals with the launching of Black Brant rocket AMF-II-115 at Churchill Research Range at night on 19 March 1971 during distinct and sustained auroral activity to carry out the launch objectives described below.

Payload engineering, fabrication and experiment integration were carried out by Bristol Aerospace (1968) Limited, Winnipeg, Manitoba, under contract to the Space Research Facilities Branch of the National Research Council of Canada. Experiments were supplied by York University, the Communications Research Centre of the Department of Communications and the Astrophysics Branch of the National Research Council of Canada. This was a recoverable payload which had previously been flown in AMF-II-117 on 18 February 1969 (SRFB 027 dated July 1969 refers).

LAUNCH OBJECTIVES

Launch objectives included photographing the auroral spectrum over the wavelength range 1000Å - 3500Å, measurements of the relative intensities and to study the profile of selected auroral features with height, to determine the ability of thin flims to survive rocket flights, to measure the intensity of specific auroral radiations in the vacuum ultraviolet in relation to visible emissions and incoming particle flux and to measure ionization density and electron temperatures.

EXPERIMENTS

Auroral Spectroscopy Experiments (Professor R. W. Nicholls, York University, Toronto)

The purposes of these experiments, which employed a spectrograph and a photometer, were to photograph the auroral spectrum over the wavelength 1000Å - 3500Å and to measure relative intensities and study the profile of selected auroral features with height.

Thin Film Test (Mr. R. Wlochowicz, Astrophysics Branch, National Research Council of Canada)

The object of this experiment was to determine the ability of thin, copper-coated polyvinyl films supported on a mesh to survive a rocket flight. Two packages were to be carried, one mounted parallel to the direction of flight and the other mounted perpendicular to the direction of flight.

Vacuum Ultraviolet Photometers (Dr. D. J. McEwen, Communications Research Centre, Department of Communications, now with the University of Saskatchewan)

This photometer package was designed to measure the intensity of specific auroral radiations in the vacuum ultraviolet region of the spectrum in relation to visible emissions and incoming particle flux. It consisted of two ionization chambers and a photomultiplier detector, each with an electrometer amplifier and a feedback network which provided a logarithmic output with a dynamic range of about 10^4. Emissions monitored were bands of the Birge-Hopfield system of nitrogen between 1100Å and 1200Å, two bands of the Lyman-Birge-Hopfield system at 1450Å and 1464Å and the N_2^+ Band at the 3914Å.

The possible application of these ultraviolet detectors for auroral intensity measurements was to be investigated as well.

Ionization Density Measurements (Dr. A. G. McNamara, Astrophysics Branch, National Research Council of Canada)

The purpose of this Langmuir type plasma probe experiment was to measure density profiles and electron temperatures.

DESCRIPTION OF THE VEHICLE

AMF-II-115 was a single-stage, solid propellant, fin stabilized sounding rocket. The vehicle used a 15KS25000 motor, serial number BAW-MT-102, manufactured by Bristol Aerospace (1968) Limited, and was fitted with a Black Brant II/V igniter housing. The four-fin Black Brant II stabilizer unit was manufactured and assembled at Canadair Limited, Montreal, with the fins set to obtain a maximum roll rate of 0.65 r/s, which would decrease to about 0.5 r/s. This unit was delivered to the range in February 1968.

The forward section of the rocket consisted of a standard Black Brant II magnesium nosecone, a forward body section and a British Aircraft Corporation Type 4, Mark 8 parachute recovery system and separation unit.

The nosecone was modified to include two pressure-tight deployable doors and a pressure-tight bulkhead at the top. The lower end was machined to accept an "O"-ring at the junction of the parallel-sided forward body.

The forward body supported the lower pressure-tight bulkhead, which carried the spectrograph and photometer and plumbing to permit evacuation of the cone and filling with helium. It was the same as that flown on AMF-II-117, except that the holes left vacant by the removal of the radar beacon antennas were used as vents. Louvres were fitted over the vent holes. The forward body featured a deployable door for the vacuum ultraviolet photometer experiment, a hole for extension of the plasma probe experiment and fixed doors for access to the arming plugs and vacuum valve.

The parachute system, which was supplied by the National Research Council of Canada, was attached via manacle and adaptor rings between the forward body and the igniter housing.

The igniter housing was a standard Black Brant V type, modified to accept the separation system, which consisted only of a pyrotechnic manacle release mechanism and a back-up firing circuit. (See Figures 1 and 2).

General Data on the Vehicle

The general data on the vehicle was as follows:

Length	878.2 centimeters
Launch Weight	1256.5 kilograms
Burnout Weight	468.6 kilograms
*Gross Payload Weight	170.1 kilograms
Propellant	Aluminized single-grain polyurethane-ammonium perchlorate
Vehicle Center of Gravity	206.7 centimeters

*Gross payload weight included nosecone, igniter housing, forward launch lug and nose attachment hardware.

VEHICLE PAYLOAD

The payload was designed to carry experiments to provide photographic and photoelectrical auroral analysis, vacuum ultraviolet and ionization density measurements and to test the ability of thin, polyvinyl films to survive rocket flights. A separation and recovery system was fitted to allow the payload to be recovered.

The experiments and instrumentation were supported by conventional aluminum dog-bones and plates, and the payload structure was modified from that flown on AMF-II-117 by the substitution of the Thin Film Test Experiment for the radar beacon system and also by the addition of current limiters.

Five Raymond G-timers were carried to control the events of door deployment, power turn-on, plasma probe extension, spectrograph flap closure and payload separation. Redundancy was provided. The heat shield release and main chute deployment were to be initiated by pressure switch closure in the parachute system.

Five battery packs were fitted in the instrumentation section, one in the parachute system and one in the igniter housing to provide internal power for the payload. Current limiters were employed to protect systems that shared batteries.

Monitors were provided for the following:

Payload heatsink temperature;
Vacuum ambient temperature;
Nosecone pressure;
50 and 70 thousand foot altitude switches;
Spectrograph, photometer and vacuum ultraviolet door deployments;
Plasma probe extension;
Payload separation;
Battery voltages;
Two-axis magnetic aspect.

TELEMETRY

Data from the payload was transmitted by an FM/FM system operating at 219.5 MHz, with one watt nominal transmitted power. The antenna system consisted of two quadraloop radiators mounted 180^{o} apart on the surface of the forward body. Polarization was linear.

Five subcarrier oscillators and four event oscillators were employed. Subcarrier oscillators used IRIG bands 14 through 18, inclusive, with modulation as described below:

Subcarrier Oscillator Allocations

IRIG Band Numbering	Center Frequency kHz	Information
14	22.0	Y-axis magnetometer
15	30.0	Plasma probe
16	40.0	Plasma probe
17	52.5	Plasma probe
18	70.0	10 x 30 commutator

Commutator channels are contained in Table 2.
Subcarrier deviation was $\pm 6\,^3/_4$ %.
Subcarrier oscillators were calibrated just prior to lift-off.

Event Channels (Sub-Commutation)

IRIG Band Numbering	Center Frequency kHz	Information
1	0.40	Motor separation monitor
2	0.56	Plasma probe extension monitors
3	0.73	Spectrograph photometer and vacuum ultraviolet monitors
4	0.96	50,000 and 70,000 feet altitude switches

RANGE SUPPORT

As this recovery flight required a launch azimuth of 170° and the riometer was fixed at an azimuth of 110°, ±20°, the request for the launch site riometer to be directed along the expected trajectory could not be met.

All-sky cameras for auroral support purposes were to be made available for operation by user personnel, and magnetometers and riometers were required to evaluate the aurora. Detailed requirements were to be provided by the project scientist at the pre-flight conference.

The three-component fluxgate magnetometer was to be manned for the night of the launching.

Four ionosonde sweeps per minute were required from T-0 to T+10 minutes. Auroral activity predictions were to be provided, with verbal reports of visual aurora during countdown and flight also given.

Real time lines from telemetry were arranged at the work bench in the operations building. A digital countdown display was installed in the user area of the operations building near the real time patch panel. Arrangements for helium and dry ice experimental requirements were agreed with and provided by the range.

Tracking

Radar skin tracking, employing two radars, was required, with plotting board data of H vs. R and X vs. Y requested at one data point per second throughout the flight of the vehicle. A copy of the real time plotting board data was required for each radar with valid track.

Sixteen mm film coverage of the range gate (negatives only), with at least six frames per second from T-0 to T+60 seconds, was necessary to verify three separate door releases.

A copy of magnetic tape with 100 pps IRIG timing of radar data was required for A-D conversion and transformation to produce tabulated data.

Ionosonde Support

The Ministry of Transport was requested to operate the ionosonde on continuous sweeps throughout the flight and provide ionograms to the project scientist during the pre-launch period.

Telemetry Requirements

All telemetry requirements were to be met by the primary telemetry station, with the backup station duplicating the primary as much as possible.

Recordings

Magnetic tape recordings were required for approximately 10 minutes, including three minutes during horizontal instrumentation checks, from T-2 minutes to loss of telemetry and for a short period following vehicle impact for post-flight calibration.

Telemetry recordings were made as follows:

Tape Track

IRIG Numbering	Information
1	Back-up video receiver #4 - 219.5 MHz
2	Prime video receiver #3 - 219.5 MHz

IRIG Numbering	Information
3	Back-up Video Receiver #2 - 219.5 MHz
4	100 kHz Reference
5	Prime Video Receiver #1 - 219.5 MHz
6	Ground Station Rubidium MAC "Y"
7	Station Multiplex*

*Multiplex subcarrier oscillator allocations:

Frequency kHz	Information
5.4	Receiver #2 Signal Strength
7.35	Receiver #4 Signal Strength
10.5	Receiver #3 Signal Strength
22.0	Receiver #1 Signal Strength
30.0	2 pps IRIG "C"
40.0	Special Timing
52.5	Voice Range Operating Command Net
70.0	100 pps IRIG "B"

Special Requirements

Vacuum Pumping and Helium Purging Equipment

This experiment required the Wadsworth spectrograph to be surrounded by a non-contaminated atmosphere until the door was ejected in the vacuum of space. Therefore, the sealed spectrograph compartment was first evacuated to 10^{-3} torr for approximately 15 minutes and then pressurized with helium. Connection of the vacuum and helium supply lines to the payload fitting were made through a small port in the Black Brant II forward body section.

York University provided vacuum pumping equipment to be available as back-up to the range-supplied pump. The range was requested to arrange for the helium supply and any necessary hoses, regulators, valves and fittings required to pressurize the spectrograph compartment to about 15 to 20 P.S.I.A. The approximate volume of the compartment is .099 cubic meters.

The user will provide sealing compound and tape needed to effect adequate joint sealing.

Note:

(1) The helium required must be 99.0% pure and contain no more than 1 part per million of oxygen, 3 parts per million of nitrogen and 6 parts per million of water.

(2) Churchill Research Range was requested to supply liquid nitrogen or dry ice for use as a vacuum pump coolant.

Recovery

Recovery of the nosecone with the payload by helicopter was required. A BAC Type 4, MK 8 para-recovery unit was used. There was no requirement to recover the expended motor. Location was by fixed-wing aircraft, and actual recovery was to be carried out in conjunction with that of AMD-VB-26. The recovered components were to be returned to main base for project scientist examination. The recovery package was necessary as the main experiment included a strip of film that was to be exposed during flight to photograph the auroral spectrum over the wavelength range 1000Å - 3000Å.

Rawinsonde release (winds only) as close to T-0 as possible was required to assist in post-flight vehicle analysis.

SEQUENCE OF EVENTS OF IMPORTANCE

Time	Event
T-0 seconds	Ignition
T+18.1 seconds	Motor burnout
T+49.2 seconds	Plasma probe extension
T+50.0 seconds	Vacuum ultraviolet experiment door ejection exposing detectors
T+58.0 seconds	Wadsworth spectrograph and photoelectric photometer experiments exposed by ejection of doors at an altitude of 70 kms
T+76.0 seconds	Photometer hi-voltage ON
T+175 seconds	Vehicle reaches apogee
T+300 seconds	Motor separation occurs
T+690 seconds	Payload impacts

LAUNCH REQUIREMENTS

This vehicle was to be launched at night during distinct and sustained auroral activity. In order to meet the desired atmospheric and auroral activity requirements, day-to-day rescheduling might be necessary. The rocket was to be launched from the universal or auroral launcher at an effective elevation angle of approximately 87^{o} and an azimuth to ensure impact of the recoverable payload in the recovery area. Maximum apogee was also a requirement.

LAUNCH PREPARATIONS

The payload of this vehicle was taken to the users' room on 6 February 1971, and work started on the payload the following day.

The pre-flight meeting was called for on the afternoon of 11 February to permit AMF-II-115 to be on the launcher on 15 February. This meeting was re-scheduled for the following afternoon at 1600. The project scientist advised the meeting that he intended to go with the nosecone in a vacuum condition, rather than over-pressured with helium gas. During payload assembly, the payload was left with the pump running, and on the following day vacuum pumping on the nosecone proved satisfactory. On Sunday, 14 February, the nosecone was still holding vacuum state.

The vehicle was placed on the auroral launcher on Monday, 15 February, and the nosecone flushed and left pumping. Vehicle payload was checked out; weather conditions were poor, with overcast skies and blowing snow.

The following day, because of SAC exercises, window time was restricted, with conditions complicated by shortening window time, snow and heavy overcast. On Wednesday, 17 February, weather was overcast during the window, and on Thursday, after some early activity, the window was relatively quiet. On Friday, 19 February, a problem developed with the York University photometer, and the payload was pulled, placed back on the rails only to have a further problem occur. This proved to be a faulty plug, which was rectified, and the payload once again returned to the rails and left pumping overnight. Payload pumping continued the following day, and on Sunday, 21 February, the payload was again ready for the vehicle.

The following week, from Monday through to Friday, was uneventful, with no suitable event, and by Saturday morning, window time ended, and the vehicle was taken off the rails and re-scheduled for a later launching between 15 and 27 March.

LAUNCHING

Since all preparations for the launching of AMF-II-115 had previously been completed, the only requirements remaining were checking out the payload, arranging range on-station times and confirmation of recovery arrangements on a time-sharing basis with other scheduled rockets.

Geophysical conditions precluded the launching of this vehicle until 2123:48 central standard time, 19 March 1971, at which time the rocket lifted off into the required conditions.

LAUNCH RESULTS

General

AMF-II-115 was launched at 2123:48 central standard time, 19 March 1971. The flight performance was good, no "drop-outs" on telemetry and all experiments worked well. Final vehicle roll rate was 0.3 r/s. Photometer, vacuum ultraviolet experiment and the plasma probe gave good, clear signals; however, the spectrograph was only partially successful. At first light on 20 March, a fixed-wing aircraft was despatched to locate the payload, and recovery action was carried out with the assistance of two ski-doos. Recovery was successful, the only damage sustained being that the tip was broken off. Arrangements were made for recovery of payload film and return shipment of material.

Tracking

One range radar (employing skin tracking) and a MK 51 Optical Tracker were employed during the flight of this vehicle. The rocket was acquired at a height of 6.6 kilometers at T+9 seconds, and the payload was tracked to impact at T+687 seconds.

Trajectory

From the radar plots furnished by the range, it was ascertained that the vehicle attained an altitude of 152.3 kilometers at T+192 seconds. Vehicle height with respect to time is shown in Figure 6.

Telemetry

Telemetry repor[illegible]d signal throughout the flight until impact of the payload at T+687 seconds.

EXPERIMENT RESULTS

Auroral Spectroscopy Experiments in the Vacuum Ultraviolet

In spite of launching into a sustained, bright auroral feature, no photographic spectrum was recorded due, apparently, to the sensitometric properties of the sample of film used.

The photometric signals appear to be mainly noise. Analyses of the records continue.

Thin Film Test

Only the films supported on the coarsest mesh suffered slight damage. There appears to be no significant difference between the damage and the film orientation.

Vacuum Ultraviolet Photometry

The door was ejected at 0324:37.3, about T+49 seconds. The photometers appeared to function normally throughout the flight. The 3914Å and LBH photometers gave good signal levels; the BH photometer did not give any appreciable signal.

On the basis of the photometer data, the rocket appeared to enter the aurora at T+77 seconds and came down through the lower edge at T+296 seconds (both times corresponding to a rocket height of slightly less than 100 km). The auroral intensity appeared to be maintained throughout the flight, but a study of rocket magnetometer and all-sky camera records is required to determine the rocket position relative to the aurora for the middle part of the flight.

Ionization Density Measurements

The onboard plasma probe was extended at the scheduled time in flight, and good plasma signals were obtained throughout the remainder of the flight. This electronics unit had been recovered from the flight of AMF-II-117 and was being re-flown.

BIBLIOGRAPHY

McNamara, A. G., Rocket measurements of auroral plasma. Bulletin of the Radio and Electrical Engineering Division, National Research Council of Canada, Vol. 15, No. 2, April/June 1965.

SRFB 017 Black Brant rocket AMF-II-116 launched at Churchill Research Range - 22 April 1968.

SRFB 027 Black Brant rocket AMF-II-117 launched at Churchill Research Range - 18 February 1969.

METEOROLOGICAL/IMPACT PREDICTION TEST SUMMARY - AMF-II-115

1. Test Number: 38.1B27015-15L Support: NRC/University of Saskatchewan, Saskatoon, and York University, Toronto

2. Date: 19 March 1971 Scheduled Time: Launch Time: 2123:48 CST

3. Vehicle Type: Black Brant II

   Objective: To investigate the properties of a stable auroral arc by utilizing auroral spectrum and vacuum ultraviolet photometry, and to conduct ionization density and thin film test measurements.

4. Motor No.: BAW-MT-102 Weight: 1086.4 kgs Length: 535.5 cms

   Payload Serial No.: AMF-II-115 Weight: 170.1 kgs Length: 342.7 cms

Complete Vehicle Weight:	Length:	Center of Gravity:
1256.5 kgs	878.2 cms	206.7 cms

5. Surface Weather Observation:

   Surface wind 025 degrees at 1 knot
   Temperature -22.2^{o} C
   Pressure 1022.0 mbs
   Visibility 15 miles - Sky clear

6. Vehicle Performance Predicted:

Sustainer impact azimuth 170^{o}	Range 41.45 kms	Time T+354 secs
Apogee altitude 139.9 kms	Range 19.96 kms	Time T+175 secs

7. Vehicle Performance Actual:

Payload impact azimuth 171.5^{o}	Range 65.7 kms	Time T+678 secs
Apogee altitude 152.3 kms	Range 33 kms	Time T+192 secs

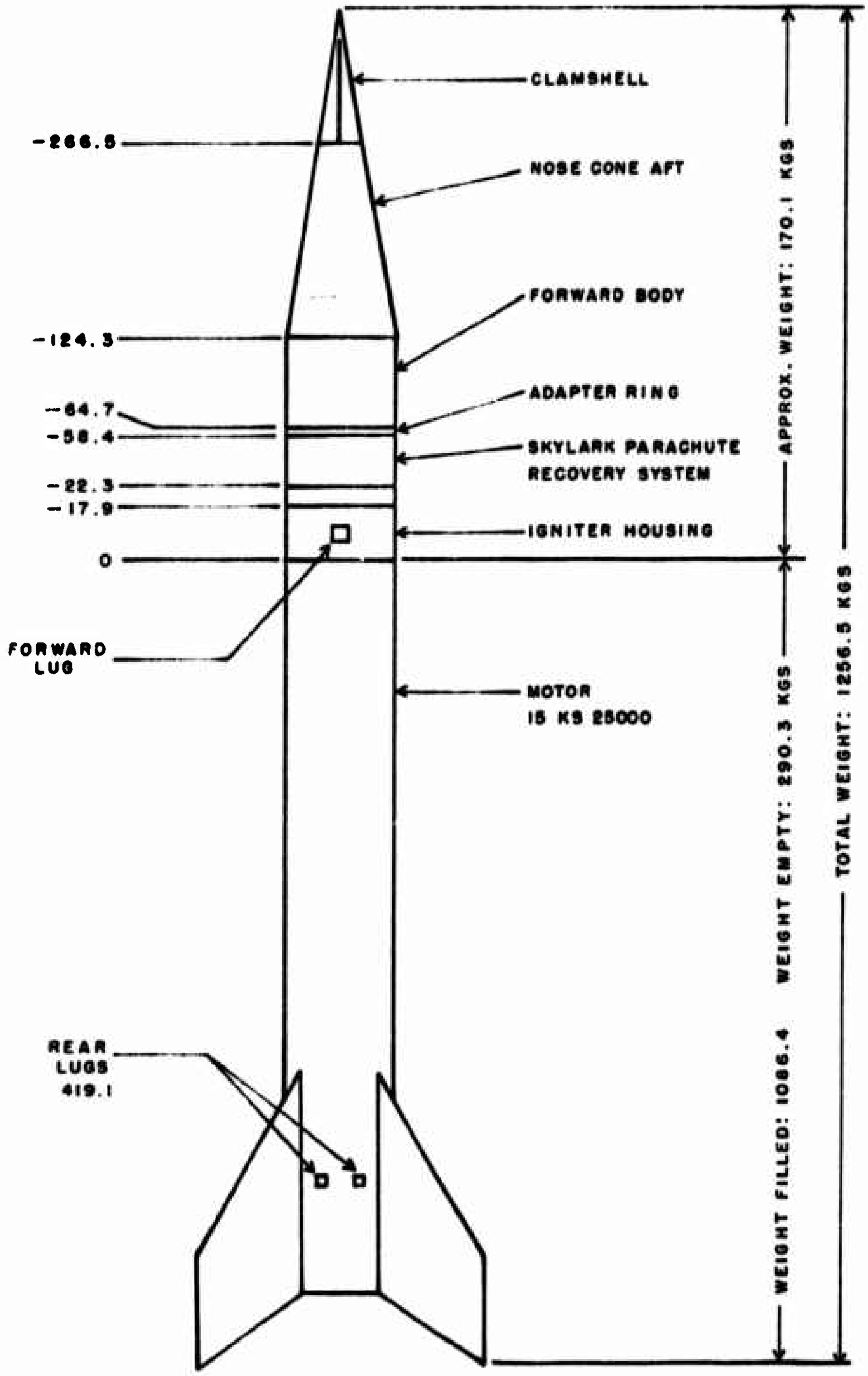
TABLE 1

AMF-II-115 COMMUTATOR CHANNELS

Channel Number	Information
1	0 Volts Calibration
2	+5 Volts Calibration
3	Vacuum Ultraviolet Photometer No. 1
4	Vacuum Ultraviolet Photometer No. 2
5	Vacuum Ultraviolet Photometer No. 3
6	Photometer
7	Photometer
8	Photometer
9	Photometer
10	Photometer
11	Photometer
12	Payload Heatsink Temperature
13	X-Axis Magnetometer
14	Plasma Channel 1
15	Plasma Channel 2
16	Plasma Channel 3
17	Vacuum Ambient Temperature
18	Vacuum Ultraviolet Photometer No. 1
19	Vacuum Ultraviolet Photometer No. 2
20	Vacuum Ultraviolet Photometer No. 3
21	Photometer
22	Photometer
23	Photometer
24	Photometer
25	Photometer
26	Photometer
27	Vacuum Gauge Monitor
28	X-Axis Magnetometer
29	Master Pulse for Synchronization
30	Master Pulse for Synchronization

TABLE 2

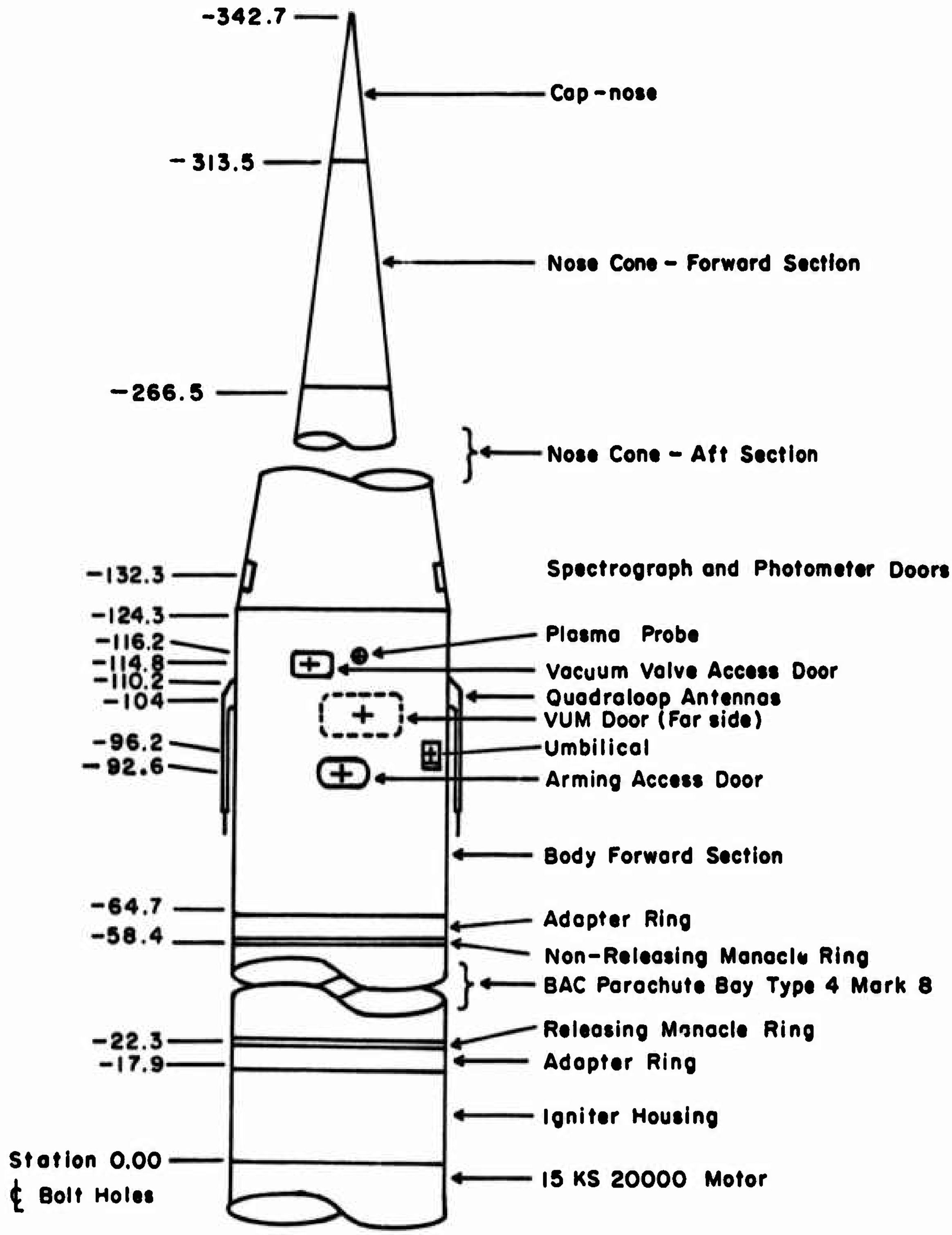
CONFIGURATION AMF - II - 115



NOTE: ALL DIMENSIONS IN CENTIMETERS

FIGURE 1

PAYLOAD LAYOUT AMF-II-115



Note: All Dimentions in Centimeters

FIGURE 2

ORDNANCE AND HAZARDOUS ITEMS AMF-II-115

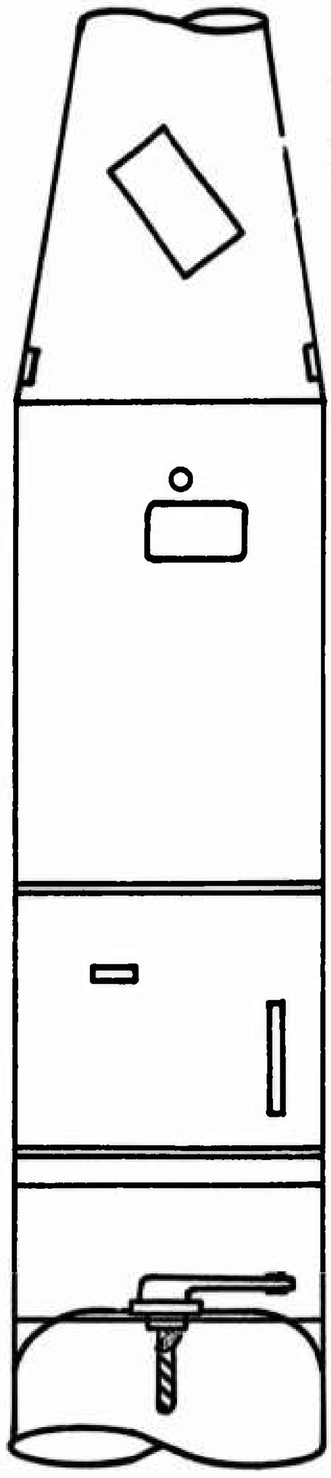
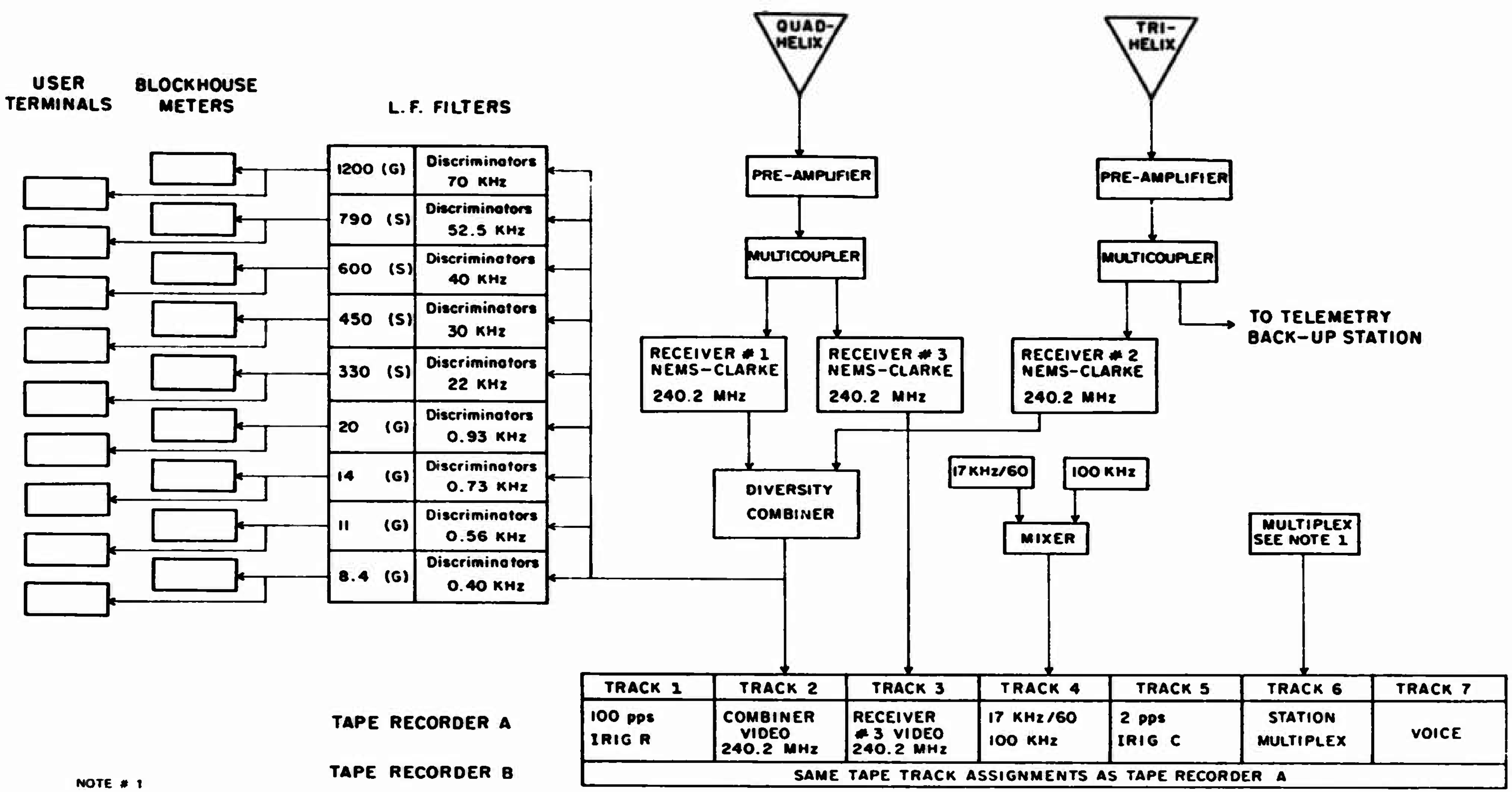


FIGURE 3

MAIN TELEMETRY GROUND STATION PLAN FOR AMF-II-115



NOTE # 1

MULTIPLEX DETAILS

70 kHz	–	100 pps Irig B
52.5 kHz	–	100 pps AMR D-5
40 kHz	–	2 pps Irig C
30 kHz	–	Receiver # 1 AGC
22 kHz	–	Receiver # 2 AGC
14.5 kHz	–	Receiver # 3 AGC

FIGURE 4

BACK-UP TELEMETRY STATION PLAN FOR AMF-II-115

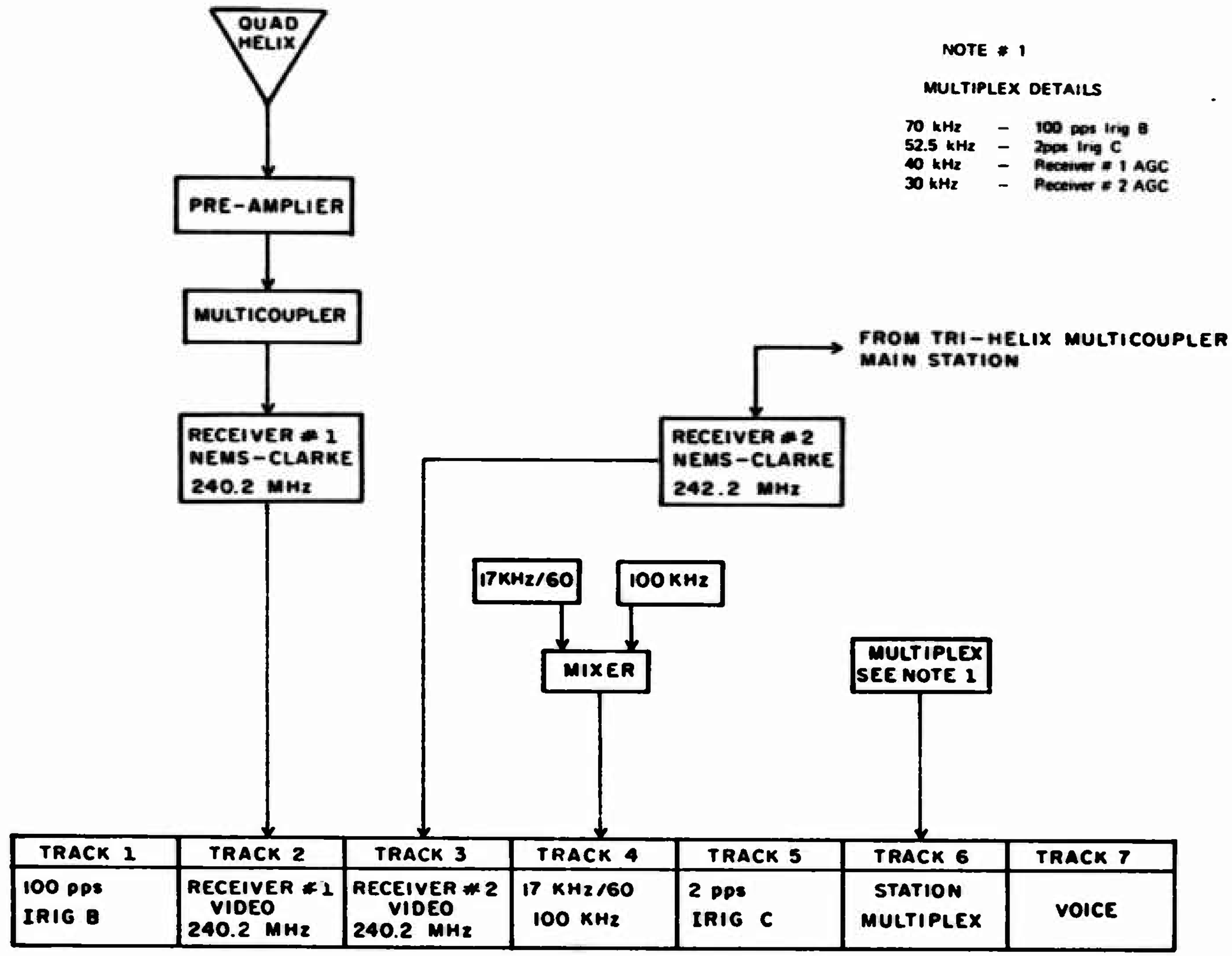


FIGURE 5

TRAJECTORY AMF - II - 115

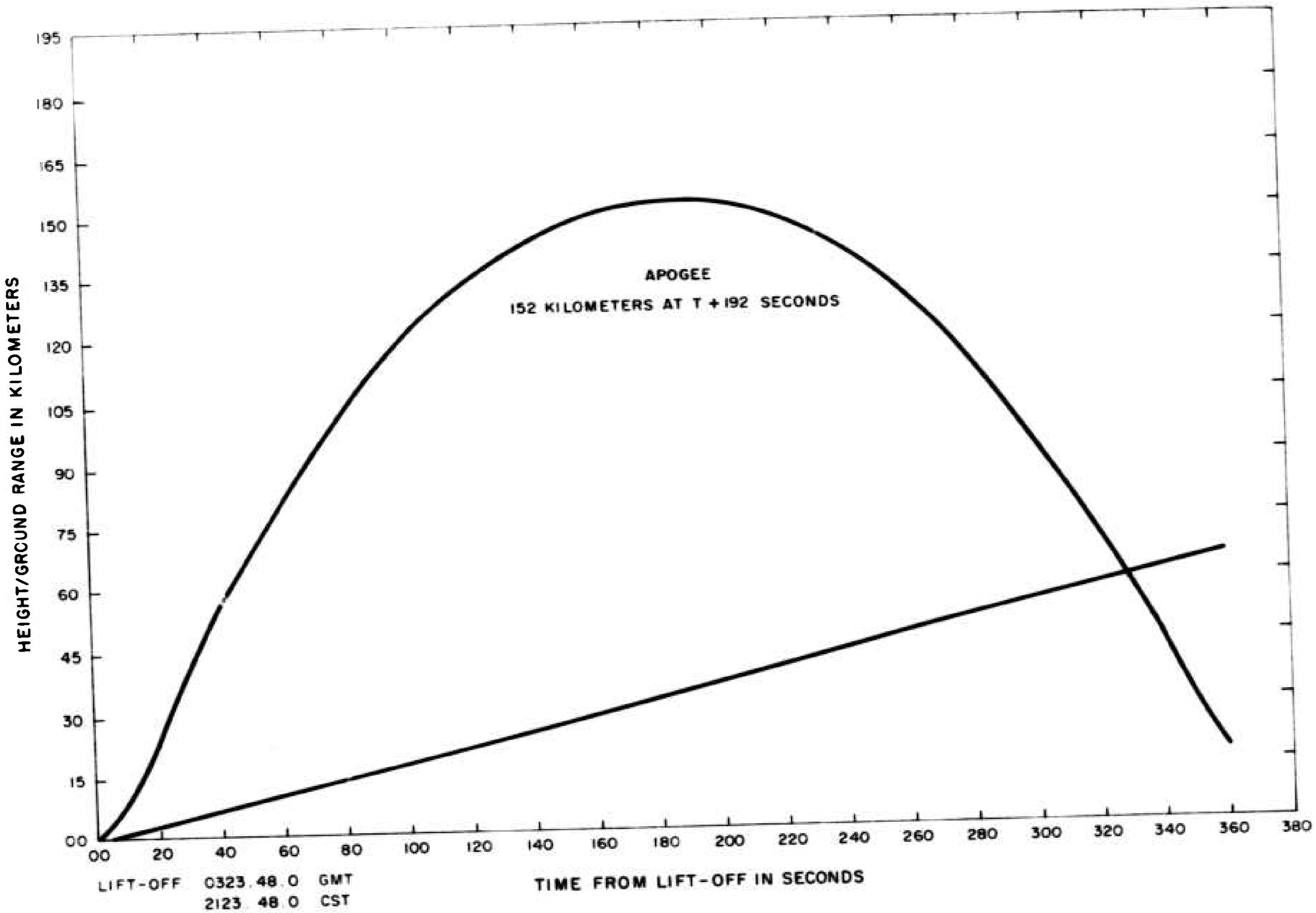


FIGURE 6

VEHICLE PAYLOAD

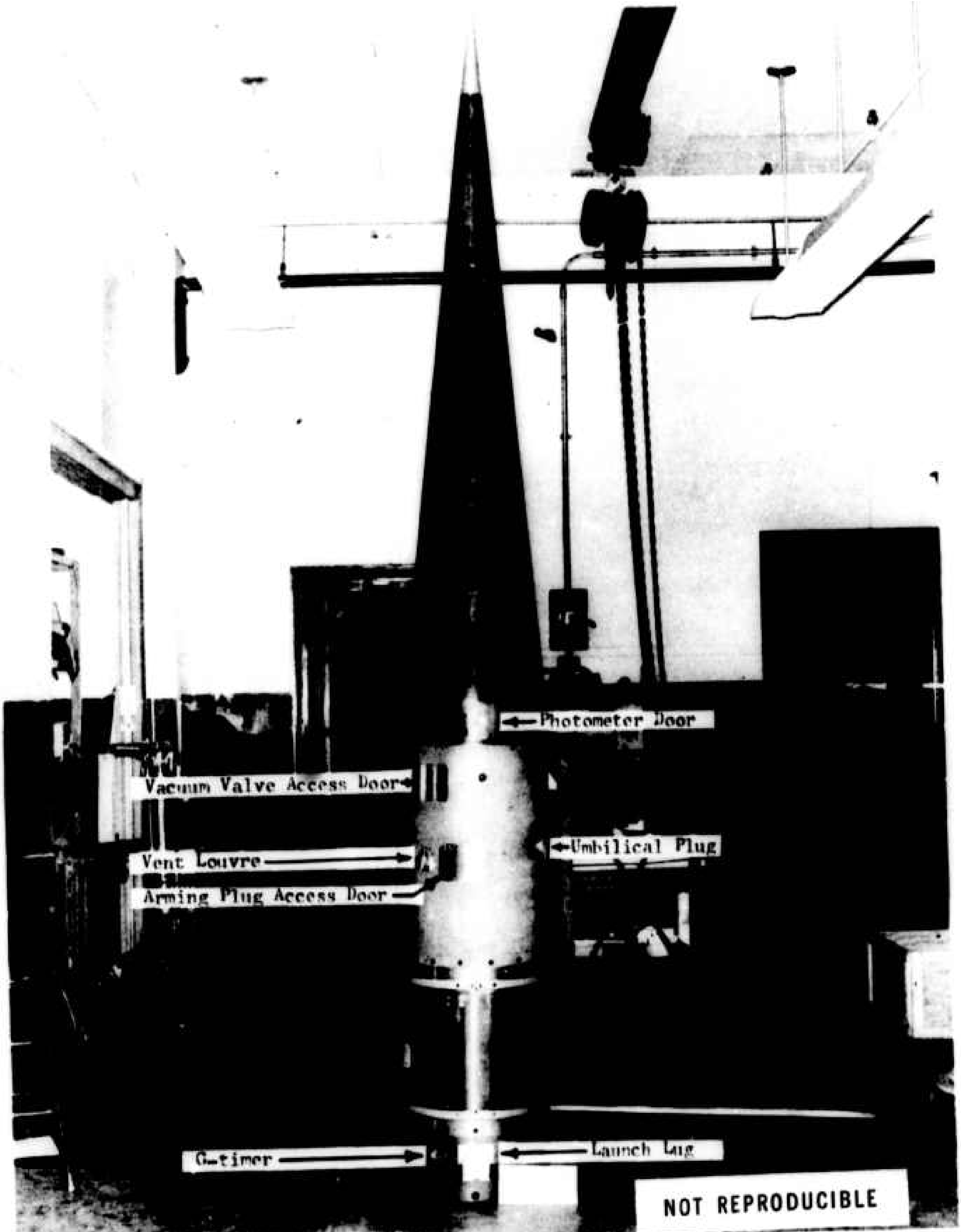


PLATE 1

NOSECONE SECTION

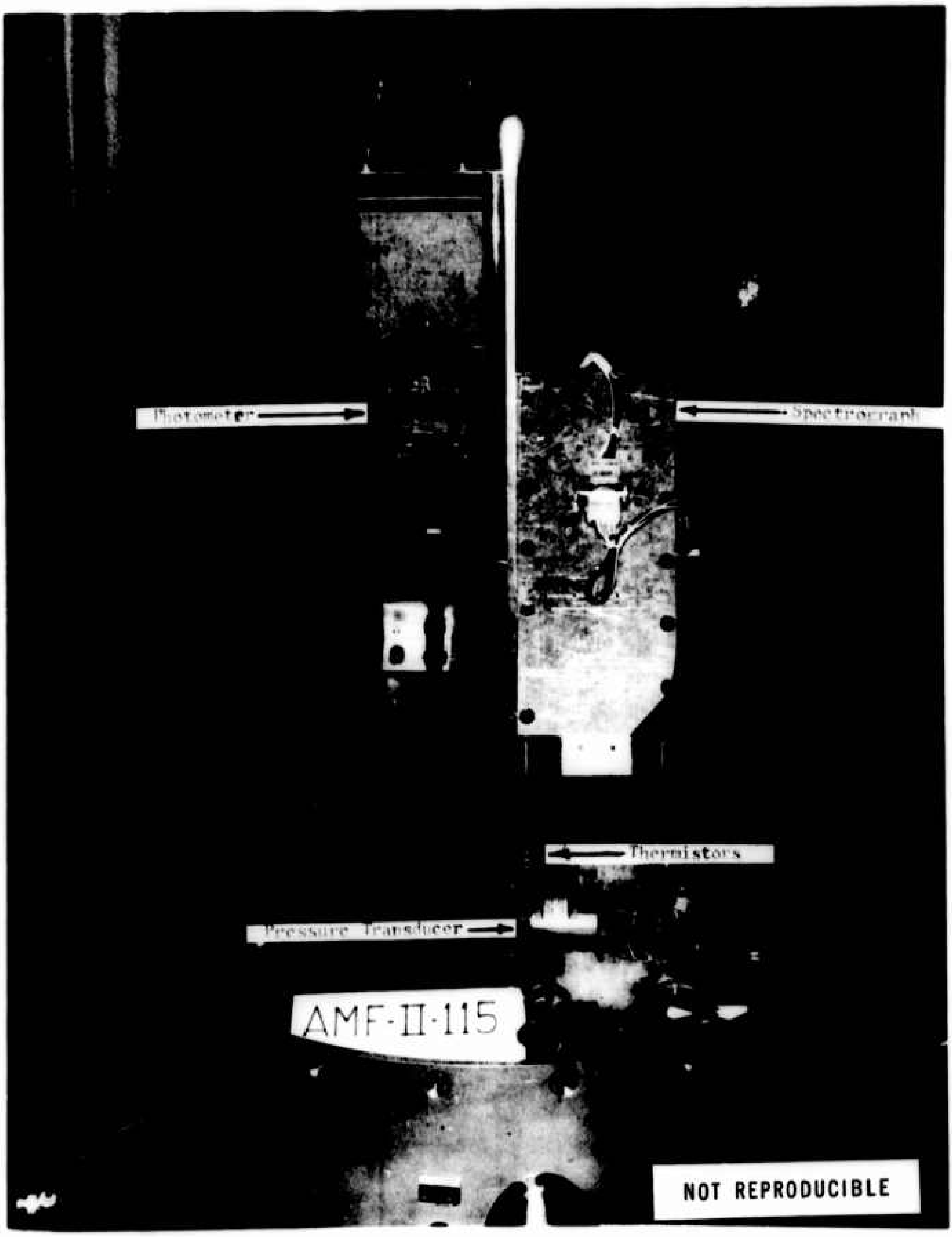


PLATE 2

PARALLEL SECTION

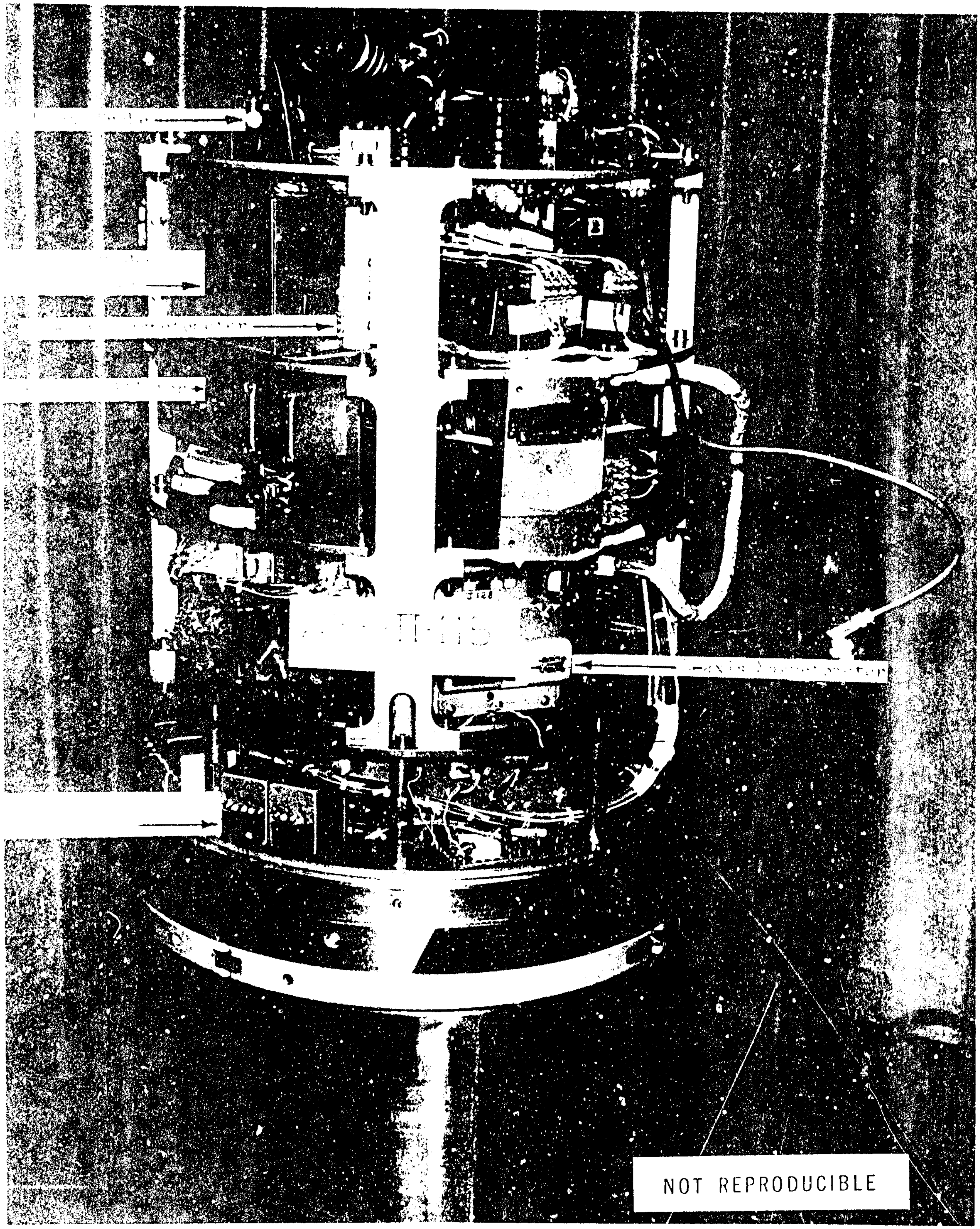


PLATE 3